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ABSTRACT

This 2-year longitudinal study explored whether computers promote more sophisticated thinking, and examined how students' thinking changes as they become experienced computer users. The first-year study examined the thinking process of four ninth-grade Apple Classrooms of Tomorrow (ACOT) students. The second-year study continued following these students as well as five new ACOT ninth graders. Over two years the research team observed lessons involving writing and writing-related activities using computers. Researchers videotaped classroom activities and kept running records of student behaviors and interactions. In daily debriefings, students explained what they were thinking during their lessons. In more general interviews, they discussed the role of the computer and their attitudes toward it. All of the students progressed markedly from the beginning of the study. They all became fluent computer users and all significantly expanded their skills, confidence, ambitions, and willingness to share their work with others. Students developed notable experience in problem solving with their computers, integrating visual representation of ideas with text, and developing, refining, and restructuring ideas through multiple drafts that included both text and graphics. During the study, researchers also observed students working with hypermedia technology in ways that suggest further possibilities for enhancing students' thinking skills. (4 references) (GL)

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Research

Student Thinking Processes

The Influence of Immediate Computer Access on Students' Thinking

First- and Second-Year Findings

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ACOT Report # 3
1989

Apple Classrooms of Tomorrow
Advanced Technology Group
Apple Computer, Inc.

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Preface

The Apple Classrooms of Tomorrow research project explores learning when children and teachers have immediate access to interactive technologies.

Apple Classrooms of Tomorrow℠ (ACOT℠) is a research project that explores learning when children and teachers have immediate access to interactive technologies. To pursue this research focus, ACOT establishes technology-rich classroom sites and encourages teachers to develop new curriculums and methods of instruction that take advantage of the technology. Within these environments, university-based researchers examine the long-term effects of the technology on teaching and learning. The project also supports R&D projects that apply current learning theories in the development of curriculums, tools, and environments that can be integrated into ACOT and other classrooms.

This research summary is one of a series of reports that documents the efforts of ACOT, in collaboration with educators and researchers, to determine how technology can be used most effectively to improve teaching and learning.

The original research reports, "The Engagement of Thinking Processes: A Preliminary Study of Selected Apple Classroom of Tomorrow Students" and "The Engagement of Thinking Processes: A Two Year Study of Selected Apple Classroom of Tomorrow Students" are available through the ERIC Document Reproduction Service, 3900 Wheeler Avenue, Alexandria, VA 22304; (703) 823-0500.

For further information about the Apple Classrooms of Tomorrow research project, contact Connie Troy-Downing, Apple Computer, Inc., 20525 Mariani Avenue, M/S 76-2A, Cupertino, CA 95014; (408) 974-5219.

Introduction

Many educators claim that computers help students develop critical thinking skills. This study explores whether computers promote more sophisticated thinking and examines how students' thinking changes as they become experienced computer users.

Most research on the impact of technology in education takes place in classrooms where learners have little access to computers—15-30 minutes a day, perhaps, but rarely more than an hour. In these environments it is unrealistic to expect the computer can be used in ways that will significantly change the way children learn or teachers teach. It is also unrealistic to expect the research to determine if any changes that do occur are actually due to the technology.

In ACOT classrooms, however, students have immediate access to computers throughout the school day and in some cases at home. The advantage of this from a research standpoint is that it permits the development of a more accurate and complete picture of technology's potential to improve both teaching and learning.

For years, computer-using-educators have claimed that computers help students develop critical thinking skills, and they have provided anecdotal evidence to support these claims. However, the need to substantiate their evidence with research data has become apparent.

When West High School in Columbus, Ohio, joined ACOT in 1986, it provided an ideal opportunity to initiate a long-term investigation of students' thinking processes. The idea was to examine how students' thinking changes as they become more experienced computer-users in a technology-rich environment. The purpose of the study was not only to find out if computers promote more sophisticated thinking, but to examine if and how students use computers while they are thinking. More specifically, the study sought to find out if students would begin using computers as thinking tools to help them solve problems and develop complex ideas.

The investigation began in the spring of 1987, just a few months after students entered the program and began using the technology throughout the school day and at home. By then, they had learned to keyboard and were fairly comfortable with the word processing, spreadsheet, and other productivity software most commonly used in their classroom. This report summarizes the longitudinal study of students' thinking processes and provides first- and second-year findings.

The Study

Overview

The first-year study examines the thinking processes of four ninth-grade ACOT students. The second-year study continues following these students as well as five new ACOT ninth graders.

Findings profile the development of students' thinking over two years and compares their progress to a second set of ninth graders who had the benefit of working with more experienced students and teachers.

This study examines over time the thinking processes of selected students in the ACOT program at West High School in Columbus, Ohio. It also explores the potential of technology as a tool to strengthen and expand students' thinking skills.

During the first year, the study examines the thought processes of four ninth-grade ACOT students. The study then continues this examination of the original students in their second year of the program. In addition, researchers follow five new ninth graders at the beginning and end of their first year in ACOT. The selected student subjects represent a cross-section of ACOT students' academic and social behaviors.

Findings at the end of the second year enable the research team to profile the development of students' thinking over two years. Their progress also can be compared to the development of the second set of ninth graders who had the benefit of working along side more experienced students and teachers.

The term, *thinking skills*, in this study refers to goal setting, knowledge building and refining, evaluation and self-monitoring, reflection and sharing. The study focuses on the types of thinking skills employed by ACOT students while working on projects (that demand word processing and other desktop publishing applications) in their combined English/social studies class.

Context—The Columbus ACOT

The Columbus ACOT is a self-contained program within a large urban high school that draws students from working class homes of mixed racial orgins. ACOT educators work as a team to provide an interdisciplinary curriculum with a

The Columbus ACOT is a self-contained program within a large urban high school that draws students from working class homes of mixed racial origins. The program began in the fall of 1986, with a class of 30 ninth graders who remained in one classroom during the morning for their core classes—English, social studies, math, and science. In the fall of 1988, the program included the original ninth graders (advanced to tenth

balance of teacher-directed, independent, and collaborative learning.

grade) and added 30 newly enrolled ninth graders and a second classroom.

All students entering ninth grade in the Columbus public school system are invited to volunteer for the ACOT program. From the list of volunteers, 30 are selected to enter the ACOT ninth-grade class. These students represent the full range of student abilities and backgrounds (racial, socio-economic, and gender) within the volunteer group.

The ACOT teachers and coordinator work as a team to provide learning experiences that integrate all subject areas. Teachers frequently team-teach curriculum units that combine subject areas, and they vary the timetable according to day-to-day needs. The physical arrangement within the classroom provides each student with a workspace that includes a desk, Macintosh® computer, external disk drive, disk container, and space for books and other materials. The classroom computers are cabled together in a network system that permits teachers and students to share files and access printers. ACOT students and teachers at the Columbus site also have Macintosh computers at home.

The instructional approach includes a mix of teacher-directed learning as well as independent and collaborative learning. The computer serves as a major resource that is well integrated into classroom use. On any given day, an observer would likely see students working on computers and interacting with one another, teachers guiding selected students, and researchers interviewing students or observing from the sidelines. During study hall and free time, the same level of activity persists as students continue to work at their computers, chat informally, or help each other with problems.

Data Collection and Analysis

Over two years, the research team observed lessons involving writing and writing-related activities using computers. Researchers videotaped classroom activities and

Over the course of two years, the research team observed series of lessons involving writing and writing-related activities using computers. In the first year, for example, the social studies and English co-teachers presented a series of lessons on death, dying, and future medical/technological advances. They introduced the

kept running records of student behaviors and interactions. In daily debriefings, students explained what they were thinking during their lessons. In more general interviews, they discussed the role of the computer and their attitudes toward it.

The study was a collaborative effort involving both Columbus ACOT staff and the Ohio State University research team.

topic with a teacher presentation (including a film) and class discussion. Then they assigned textbook readings and asked each student to write a paper on one of several suggested topics. Class time was available for students to plan, draft, share, and revise their work.

During their observations, researchers kept two sets of records: videotapes of classroom activities and minute-by-minute written records of teacher interactions and individual student behaviors. The written records provided a basis for conducting daily debriefings with the students who were being closely examined. In these one-to-one interviews, researchers asked students to explain what they were thinking during the previous day's writing lesson. The purpose was to explore the nature of thinking students were engaged in during the lesson.

Later, researchers conducted more general interviews with individual students to gain a broader perspective on the role of the computer and the students' attitudes toward the computer in school and at home.

All the interviews were transcribed and analyzed by researchers and the Columbus ACOT staff. Categories for coding the information identified the types of thinking processes employed by students and the role of the computer in these processes. Categories for the daily interviews addressed students' thinking processes while working on writing assignments, including strategies for planning, drafting, revising, and completing the assignments. Categories for the general interviews addressed topics that range from interactions with peers to home use of computers. Both the original observer and another person reviewed and independently coded every comment offered by the student. Generalizations and hypotheses emerged as researchers and ACOT personnel reviewed the data.

The study, especially the development of interviews, generation of coding schemes, and consideration of findings, was a collaborative effort involving both the Columbus ACOT staff and the Ohio State University research team.

The Findings

Findings indicate that it usually takes at least a year for individuals to become computer competent such that significant changes in teaching and learning occur. However, when mentors are readily available, positive changes occur much more rapidly.

This study amplifies the importance of long-term research on how technology affects teaching and learning. Findings from this study reveal that it usually takes at least a year for individuals (who are computer novices and without mentors) to be comfortable and competent with computers such that significant changes in teaching and learning occur. The study's first-year results do reveal positive changes, but it is during the second year that the more significant positive changes occur. Also noteworthy is the fact that when teachers and students who are new to computers have experienced mentors readily available, significant positive changes occur much more rapidly.

The first- and second-year findings of this study identify the types of changes in students' thinking that occurred within the first year of using technology on a daily basis, as well as those changes that took longer.

The First Year

During the first year, computer use contributed to growth in students' self-confidence, willingness to meet new challenges, and development of thinking strategies.

Generally, the first-year findings suggested that in ACOT, the use of computers contributed to growth in students' self-confidence, willingness to meet new challenges, and development of thinking strategies.

Students' Thinking While Engaged in the Writing Process

The ease with which computers can be used to make text revisions prompted students to explore topics and record ideas more fully, as well as reflect upon these ideas. They used early drafts to explore and expand their thoughts and later drafts to refine them.

Over the year, students used their computers continually for both drafting and revising text. In these areas, the computer made a significant contribution to the students' exploration of ideas. Their comments suggested that they not only thought more, but they were more fluent as a result of developing their ideas on the computer. Because the computer implemented their alterations so easily, it prompted some students to explore topics and record ideas more fully, as well as reflect upon these ideas and discuss them with peers.

In the first year, most of the students' revisions occurred as they reviewed printed text rather than text that was on the screen before printing.

Their research on a topic was generally limited to their own thoughts and what teachers did to prompt thinking.

For the most part, the ninth graders' research on a topic was limited to their own thoughts and what the teachers did to prompt thinking (in this case, films, class discussion, and assigned readings). Sometimes students used their peers or teachers as resources, but more often they generated ideas from personal experiences and then organized them in their heads before writing. Some students used the computer to generate lists of ideas that they mulled over and used as a basis for their drafts.

Over the year, students did develop quite sophisticated thinking strategies. For example, they all approached the exploration of topics across more than just one draft. They used early drafts to explore and expand ideas and later drafts to edit and refine them. Students were also aware of the value of creating some distance from their own text in order to revise it. By printing out the text and inviting others to read and comment, they were able to gain a more objective perspective on what they wrote. They also learned how others develop text and received helpful suggestions for change. All of the students noted the importance of a final proofreading and editing, which they completed by reviewing a printout just before printing the final draft.

Interestingly, most of the students' revisions occurred as they reviewed printed text. They made few revisions while the text was on the screen before printing, and these revisions were generally restricted to additions and corrections. They did little in the way of deleting, reorganizing, and refining their ideas.

Thinking Processes in Other Activities

Students developed new information management techniques (using spreadsheet and database software) and new strategies for expressing ideas (with graphics, tables, and charts). Experiences such as these helped them take greater responsibility for learning.

During the first year, students developed new information management techniques that included collecting, categorizing, and sorting information using database and spreadsheet software. They also developed new strategies for expressing ideas such as using graphics, tables, and charts to clarify or emphasize particular concepts. Through these and other computer-based experiences they gained a sense of responsibility for learning.

At the close of the first year, students did not feel that they learned differently with the computer, but they did

In the first year, students did not claim they learned differently with the computer; however, they did claim that learning was more challenging and that they learned more advanced material.

Students used their home computers for homework and for self-initiated projects.

claim that learning was more challenging and that they learned more advanced material.

Students' comments indicated that the home computer played an integral role in promoting writing and thinking. All of them preferred to write at home where they were less distracted by classroom activities and noise level. They said that their home computers helped them be more organized and produce better quality work. Besides homework, students used home computers for self-initiated projects. One student used his for a private business venture (making posters and other saleable products), another used hers to help family members and neighbors write letters, and all of the students enjoyed playing computer games at home. In addition, the home computers helped parents understand what their children were learning in the classroom and enabled all family members to share the ACOT experience.

The self-contained ACOT environment fostered student interactions, including feedback and problem-solving sessions as well as collaborative work on projects. Teacher-student relationships were close and mutually respectful.

Students' dissatisfactions in the first year included some students' discomfort with sharing, limited contact with non-ACOT peers, and frustration with various technological problems.

Interactions with Teachers and Other Students

At the end of the first year, students claimed that their relationships with ACOT teachers and students were much closer and more interactive than in regular classrooms. The relationship between ACOT students and teachers was one of mutual respect. Students viewed their teachers as "caring" and appreciated being treated as members of the instructional team. Throughout the year, simultaneous learning occurred as teachers and students joined forces to explore new software and new approaches to covering the curriculum.

The ACOT environment provided many opportunities for students to interact with one another. Students met in peer conferences to solve problems or provide editorial feedback. They worked on cooperative projects in which they planned and produced products. They also interacted spontaneously whenever they needed help. In addition, the physical nature of the self-contained ACOT area contributed to student interactions as did the staff's successful establishment of an "ACOT family."

On the other hand, at the end of the first year, some students still lacked the necessary confidence and skills to feel comfortable interacting with others in small groups. For instance, one student said he felt uncomfortable reading aloud and sharing his work with classmates.

The computers also created some drawbacks. Students said that the small size of the screen and print made reading text difficult. Consequently, most of them printed out their work rather than revise it on the screen. Other concerns included the lack of a word processing feature that would allow students to add comments and corrections in the margins of each others' papers, the difficulty some had learning new software, disk crashes, and the need for additional desk space to keep books, papers, and other materials.

Interactions between ACOT students and students outside the program were limited. ACOT students indicated that the other students had little understanding of what occurred in the ACOT area and that some resisted involvement because they lacked computer skills. It seemed as if the others viewed ACOT students as special and what occurred in the program as mysterious.

The Second Year

The longitudinal nature of the study enabled researchers to examine students' development over two years and thereby gain a clearer view of the influence that computer technology had on students' thought processes.

The second-year study extended the investigation of the relationship between the computer, writing, thought, and learning in the ACOT classroom. The study's longitudinal approach called for a re-application of similar measures in order to follow student growth and development over time. Researchers again observed and interviewed the original four students, who were then experiencing their second year of ACOT. In addition, researchers applied similar measures to five ninth-grade students at the beginning and at the end of their first year in the program.

Second-year data enabled researchers to compare ninth graders in the start-up year to ninth graders in the second year of the program. The data also permitted researchers to examine the tenth graders' development over two years. By making these comparisons, the research team was able to attain a clearer view of how and to what degree the influence of computer technology had upon students' thought processes.

Newly Enrolled Ninth Graders

By the end of their first year in ACOT, these ninth graders had progressed well beyond the planning strategies used by the previous year's ninth graders. These students incorporated ideas from peers and other resources, and they considered audience and how their projects might be strengthed by graphics. Students used graphics to complement both the development and presentation of ideas. Computer graphics served to stimulate the processes of thinking and writing.

Students' Thinking While Engaged in the Writing Process

Similar to the previous year's ninth graders, the newly enrolled students tended to begin writing with just their own thoughts and the teacher's suggestions. As the year progressed, however, their use of resources extended to peer input from within and across classes. Jot lists (used in preparation for writing) gave way to more complex mental representations that students used to shape their thoughts both before and during drafting. They incorporated what they read and also gave careful consideration to the audience and how their projects might be strengthened by graphics. At the end of the year, this group of ninth graders had progressed well beyond the planning strategies used by the previous year's ninth graders.

The extensive graphics options available with the Macintosh became a vital feature in student writing over the year. Students used graphics to complement both the development and presentation of ideas. Teachers remarked that graphics helped many of the students "get going" when previously they might have found it difficult to begin. Computer graphics assumed an important role in motivating writing and in forming and prompting thinking. For instance, students used graphics to present ideas that they could express more accurately and completely with pictures than they could with words. By the end of the year, these ninth graders were using graphics in more creative and adventurous ways than their tenth grade counterparts had the year before.

The graphics capabilities of the Macintosh provided students with visual tools to explore and develop ideas in all academic areas.

Thinking Processes in Other Activities & Interactions with Teachers and Other Students

This group of ninth graders also developed a variety of information management abilities, ranging from using spreadsheets to graphically simulating phenomena in science and mathematics. These new abilities enhanced their academic learning as well as the work they did outside of ACOT.

Over the course of the year, the graphic capabilities of the Macintosh guided rhetorical discussions and provided the students with visual tools to explore and develop

ideas in all academic areas. As students explored topics in science, mathematics, and social studies, the graphics prompted them to examine visual representations of information. And as they developed their own projects, they considered the use of graphics to introduce and extend ideas.

Just as the previous year's ninth graders, these students preferred the ACOT classroom over the regular classroom. They liked the support that the teachers, peers, and tenth graders provided them.

These ninth graders also used the computers at home for both school-related and personal tasks. Parents occasionally used the computer to play games with their son or daughter, monitor homework, and do their own correspondence or work-related activities.

Tenth Graders in their Second Year of the Program

Second-year ACOT students developed increasingly more sophisticated planning strategies. They consulted with peers and other resources and demonstrated attention to genre and point-of-view.
In year two, writers' on-screen revisions included more substantial alterations such as reshaping and reorganizing text on the screen. They sought peer feedback more often and generally claimed to be more fluent, better organized, and more successful writers with the computer.

Students' Thinking While Experiencing the Writing Process

Over the course of two years, students developed increasingly more sophisticated planning strategies while using their computers. Research of a topic included considerably more interaction with peers as they explored plans for their texts. Students demonstrated considerable consideration for genre, outside resources, logistical constraints (e.g., deadline, length), and point-of-view.

Some students continued to write from jot lists while others wrote their ideas in sentences, understanding that they could reorder and revise these ideas through multiple drafts. As in year one, the tenth graders made extensive use of the computer for developing and refining their thoughts, using early drafts to explore and expand ideas and later drafts to edit. During the first year, writers' on-screen revisions were limited to additions and corrections. In year two, however, revisions included more substantial alterations such as reshaping and reorganizing text on the screen. There was also a growing realization of the value of obtaining outside reviews. As a result, students significantly increased the number of self-initiated requests for peer feedback.

Second-year students claimed they were more fluent and better organized writers. They said that writing was easier for them with the computer and they believed that the quality of their writing had improved.

Over two years the students developed such competence with the computer that they used it more readily than pencil and paper.

The addition of hypermedia, interactive video, and robotics technologies radically changed the way students learned. They were more actively involved in designing and building curriculum projects and hence more responsible for constructing their own knowledge.

Thinking Processes in Other Activities & Interactions with Teachers and Other Students

Over the course of two years, students developed such comfort and competence with the computer that they used it more readily than pencil and paper. By the end of the second year, students were familiar with over 40 software tools that they selectively used for various academic projects. Their daily experiences included solving problems with computer simulations; representing ideas with graphics, animations, and video; and reworking ideas with the easy revision capabilities in all of their software.

In year one, students remarked that the computer did not change how they learned, but that it made learning more challenging. In year two, however, they claimed that the addition of hypermedia, interactive video, and robotics technologies radically changed the way they learned. When they created HyperCard® software stacks or robotics constructions, for example, they had to solve design and construction problems as they completed the projects. Then they used these projects to teach classmates the related curriculum concepts. This method of learning was very different from the traditional method of studying a textbook, completing assigned problems, and taking a test. When using these technologies, students were more actively involved in designing and building curriculum projects and hence more responsible for constructing their own knowledge.

General comments about the program tended to echo what students said after the first year. They remained self-confident and enthusiastic about their work with computers. They continued to use their home computers for homework and outside activities. And they continued to express frustrations concerning the small computer screen and difficult-to-read type, learning to use complex software, disk crashes, and so forth. All students interviewed preferred the ACOT classroom over the regular classroom, stating that students and teachers were much more willing to help one another. After two years, the tenth graders still viewed the ACOT program positively as "one big happy family."

Overall Summary

All of the students progressed markedly from the beginning of the study. They all became fluent computer users and all significantly expanded their skills, confidence, ambitions, and willingness to share their work with others. Students developed notable experience in problem solving with their computers, integrating visual representations of ideas with text, and developing, refining, and restructuring ideas through multiple drafts that included both text and graphics.

In ACOT, computer use was integrally woven into the fabric of classroom life and student learning during the two-year period. Overall findings indicate that ACOT students developed a sense of purpose that incorporates the pursuit of excellence and an understanding of the relevance of classroom learning to the outside world. Students were self-confident about their computer skills and indeed, the computers were so handy that students used them more readily than pencils and paper. Students developed notable experience in problem solving with their computers, integrating visual representations of ideas with text, and developing, refining, and restructuring ideas through multiple drafts that include both text and graphics.

Over the two-year period, both ninth and tenth graders demonstrated an expanding repertoire of planning and revision behaviors. Several students noted that the movement from handwritten text to computer-generated text prompted them to review their ideas and written work more readily. The electronic medium also fostered an increasing willingness to share their work with others.

All of the students progressed markedly from the beginning of the study. They all became fluent computer users and all significantly expanded their skills, confidence, and ambitions.

Implications for the Future

During the study, researchers observed students working with new hypermedia technology in ways that suggest further possibilities for enhancing students' thinking skills. Take HyperCard, for instance. Its multimedia, multilayered text capabilities appear to have the potential to add a new dimension to students' ideas

The present study explores the potential of an ACOT classroom to enhance thinking skills and the role of computer technology in achieving this potential. The findings of the study suggest that, in ACOT, the use of the computer has contributed to a growth in the confidence of students of varying ability, an increase in their willingness to strive to meet new challenges, the development of a repertoire of strategies for thinking, and an increase in students' awareness of their own expertise.

During the study, researchers observed students working with new hypermedia technology in ways that suggest further possibilities for enhancing students' thinking

of "writing" and the nature of written text.

HyperCard raises important questions regarding the extent to which hypermedia might enhance learning and change communication. For example: How do reading and writing differ with this new technology? In particular, do students engage in different thought processes when reading and writing hypermedia texts?

skills. Take HyperCard software, for instance. Its multimedia, multilayered text capabilities appear to have the potential to add a new dimension to students' ideas of "writing" and the nature of written text.

HyperCard technology gives writers the opportunity to incorporate multiple medias in one "text." HyperCard texts include animation and graphics, and can connect the computer to a videodisc player to play selected segments of color video. Readers can choose the routes they take through the contents because they can move through it in a nonsequential order. HyperCard texts also have multiple layers of information; there are specific places in the text where readers can request additional information. The text then displays information (in multimedia formats) not previously visible to the reader.

The possibility of multimedia texts seems to have already had an impact on students in the ACOT classroom. In particular, ACOT students introduced to HyperCard are seeing the computer not only for its computational abilities but also for its representational abilities. These representational abilities are changing the students' conceptions of text from a rather static view to a more dynamic one. With a static view, students tend to adopt a rather passive approach to text processing that involves linear rather than recursive negotiations. A more dynamic view engages students to consider a variety of possible routes and shifts in direction.

For the educator, HyperCard raises several important questions regarding the extent to which hypermedia might enhance learning and change communication. For example: In what ways do reading, writing, and learning differ with this new technology? In particular, do students engage in different thought processes when developing multimedia, multilayered texts? Do students' views of the texts they are developing differ? Do students establish different goals for themselves as readers, writers, and learners? Further research that examines these and other such questions is critical in determining how technology can best be used to develop students' thinking skills.

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